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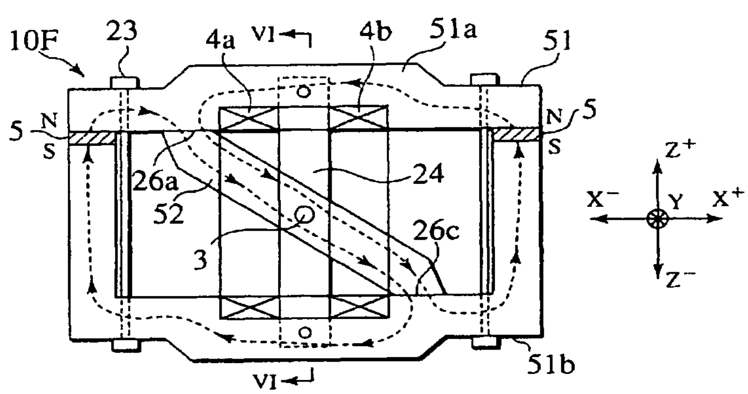
(54) Rotary operating mechanism for switchgear

(57) A rotary mechanism for operating switchgear has a fixed core, a rotary core rotatable within a rotation range limited by end positions corresponding to switchgear open and closed positions, a spring unit for accumulating resilience when the rotary core is rotated to any one of the end positions, a permanent magnet for generating attraction greater than the resilience of the spring unit, to hold the rotary core at any one of the end positions, and an electromagnetic coil for forming, when the rotary core is at one of the end positions, a magnetic path to weaken the attraction of the permanent magnet lower than the resilience of the spring unit so that the rotary core may be rotated to the other end position where the permanent magnet and electromagnetic coil form magnetic paths oriented in the same direction. This rotary operating mechanism has a wide application range, a bistable characteristics, a permanent magnet attraction switching function, and a long switching stroke.

FIG.3A



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a rotary mechanism for operating switchgear such as circuit breakers and disconnecting switches.

2. Description of the Related Art

[0002] Conventional switching mechanisms for switchgear are mainly of mechanical type. The mechanical-type switching mechanism accumulates energy in a spring by driving a motor and releases the accumulated energy by unhooking a mechanical catch, to carry out a switching operation. Recently employed switching mechanisms are of electromagnetic actuator type that uses permanent magnets and electromagnetic coils.

[0003] Figures 1A to 1C show the structure and operation of a typical electromagnetic actuator mechanism for driving a vacuum valve of one phase of a vacuum breaker. The same mechanism is usable to collectively control the vacuum valves of three phases of a vacuum breaker. Through the drawings, any magnetic path or circuit formed by a permanent magnet is depicted with a dashed line and that formed by an electromagnetic coil is depicted with a solid line. In Fig. 1A, the structure has a fixed core 83 and a movable core 84. The movable core 84 is arranged at the center of the fixed core 83 and is linearly movable along an axis of the fixed core 83. Between the fixed core 83 and the movable core 84, a permanent magnet 85 is magnetized substantially perpendicular to the axis of the fixed core. Two electromagnetic coils 86a and 86b surround the movable core 84. The movable core 84 is connected to the vacuum valve (not shown) of the vacuum breaker (not shown) through a movable shaft 88. Between the movable core 84 and a vacuum valve contact, there is a wiping spring 89 for applying constant compression force to the contact in a closed or connected state.

[0004] In Fig. 1A, the breaker is in a disconnected or open state with no current. As indicated with a dashed line, the magnet 85 forms a magnetic circuit that starts from an inner magnetic pole (N), passes through the movable core 84 and fixed core 83, and reaches an outer magnetic pole (S). Due to the magnetic circuit, the movable core 84 is attracted by a lower face 87a of the fixed core 83, to maintain the open state of the breaker. In Fig. 1B, the closing coil 86b is excited to generate a magnetic field oriented in a longitudinal direction (Z). Magnetic flux from the coil 86b passes through the fixed core 83 and movable core 84 and returns to the coil 86b to form a magnetic circuit depicted with a solid line, which is oriented opposite to the magnetic circuit formed by the magnet 85. As a result, the solid-line magnetic circuit cancels the dashed-line magnetic circuit around the lower face 87a of the fixed core 83. This weakens the attraction of the lower face 87a on the movable core 84. At this time, magnetic flux density around an upper face 87b of the fixed core 83 increases to strengthen the attraction of the upper face 87b on the movable core 84. As a result, the movable core 84 is upwardly attracted to start a closing or connecting operation. In Fig. 1C, the closing operation is just before completion. In this state, magnetic flux from the magnet 85 is biased to the upper face 87b to form a magnetic circuit (a dashed line in Fig. 1C) that is oriented in the same direction as the magnetic circuit of the coil 86b. Namely, the magnetic circuits of the magnet 85 and coil 86b enhance each other to upwardly attract the movable core 84 and compress the wiping spring 89, to complete the closing operation. The attraction of the magnet 85 is designed to overcome the resilience of the wiping spring 89 after the completion of the closing operation, so that the movable core 84 is kept attracted to the upper face 87b to maintain the closed state with no current.

[0005] Figure 2 is a graph showing the relationship between attraction on the movable core 84 and a stroke of the movable core 84 in a closing operation with upward attraction being positive. A dashed line represents attraction by the magnet 85 alone, and a solid line represents total attraction when the coil 86b is excited in a closing direction. A dot-and-dash line represents the resilience of the wiping spring 89 that originally works in a negative direction Z- but is sign-inverted in the graph. A point A is a disconnected or open position of the movable core 84 where the movable core 84 is attracted to the lower face 87a. When the coil 86b is excited, the movable core 84 receives resultant upward attraction that is higher than the force of the wiping spring 89, to complete the closing operation at a point B. During the closed state with no current, the attraction C of the magnet 85 alone surpasses the force D of the wiping spring 89, to maintain the closed state.

[0006] Magnetic paths to be formed during an opening or disconnecting operation are opposite to those of the closing operation. For the opening operation, the compressed wiping spring 89 downwardly accelerates the movable core 84, to quickly complete the opening operation. In Figs. 1A to 1C, the two coils 86a and 86b serve for the opening and closing operations, respectively. Instead, the coils may be connected in series and may oppositely be excited to achieve the opening and closing operations.

[0007] The electromagnetic actuator mechanism mentioned above has two advantages. First, the mechanism provides a bistable characteristics by forming two stable magnetic circuits. The mechanism maintains the open and closed positions of a breaker only with the attraction of a permanent magnet, to eliminate a special fixing mechanism or power, reduce the number of parts and costs, and elongate service life compared with mechanical switching mechanisms. Second, the mechanism excites a coil to reduce the attraction of a magnet

to start moving the movable core, and at the end of the movement, changes magnetic paths to enhance the attraction of the magnet and compress a spring. The second advantage is an attraction switching function.

[0008] This prior art, however, has a problem of suddenly losing the attraction of permanent magnets and electromagnets as a pole-to-pole gap widens. Due to the problem, the prior art has a narrow application range. Namely,.it is applicable to a movable-core stroke of about 20 mm or shorter and is inapplicable to longer strokes. In Figs. 1A to 1C, the movable core 84 is linearly moved in principle. It is not common, however, to directly connect the driving shaft of an actuator mechanism to a switchgear shaft. In some case, the driving shaft of an actuator mechanism must be connected to a switchgear shaft through a rotary lever to convert linear motion into rotary motion to open and close the switchgear. In addition, some switchgearmust be opened and closed by rotating a contact. It is required, therefore, to provide a rotary mechanism for operating switchgear.

SUMMARY OF THE INVENTION

[0009] An object of the present invention is to provide a rotary mechanism for operating/actuating switchgear that is compact, simple, and capable of carrying out opening and closing operations through rotation, realizes awide scope of application, a bistable characteristics, an attraction switching function, long-stroke opening and closing operations, high reliability, reduced power consumption, high-speed response, and strong holding power.

[0010] In order to accomplish the object, a first aspect of the present invention provides a rotary mechanism for switchgear, having a fixed core, a rotary core rotatable with respect to the fixed core within a rotation range limited by end positions corresponding to switchgear open and closed positions, a spring unit for accumulating resilience when the rotary core is rotated to any one of the end positions, a permanent magnet for generating magnetic flux to form a closed magnetic path passing through the fixed core and rotary core when the rotary core is rotated to any one of the end positions, the magnetic path generating attraction greater than the resilience of the spring unit, to hold the rotary core at the end position, and an electromagnetic coil for generating, when excited with the rotary core being at one of the end positions, magnetic flux to form a magnetic path oriented opposite to the magnetic path formed by the permanent magnet, the magnetic path formed by the electromagnetic coil weakening the attraction by the permanent magnet lower than the resilience of the spring unit so that the rotary core may be rotated to the other end position where the permanent magnet and electromagnetic coil form magnetic paths oriented in the same direction.

[0011] The first aspect links the rotation of the rotary core to switchgear opening and closing operations, and therefore, the first aspect is applicable to switchgear that opens and closes contacts through rotation. At the end positions , the first aspect provides a bistable characteristics to maintain an open state or a closed state only with the attraction of the permanent magnet. The spring unit accumulates resilience converted from rotation energy generated by the rotary core. The resilience avoids the rotary core from strongly hitting the fixed core at each end position, thereby improving the reliability of the rotary mechanism. The resilience also serves force for driving the next rotary operation of the rotary core, thereby reducing an excitation current or power for the rotary operation. To start an opening or closing operation, the first embodiment excites the electromagnetic coil to generate magnetic flux that weakens attraction by the permanent magnet, so that the rotary core may be rotated by the resilience of the spring unit. When the rotary core is rotated close to the other end position, the magnetic flux of the coil enhances, contrary to the start of rotation, the attraction of the permanent magnet and helps compress the spring unit. This attraction controlling function by the coil as well as the moment of inertia of the rotary core realize long-stroke opening and closing operations.

[0012] A second aspect of the present invention makes ends of the rotary core be attracted by predetermined parts of the fixed core, respectively, when the rotary core is rotated to any one of the end positions. The second aspect arranges the permanent magnet on part of the fixed core within the rotation range of each end of the rotary core, the permanent magnets being oriented so that their magnetic poles may repel each other. In addition, the second aspect arranges the electromagnetic coil to surround the rotary core. At any one of the end positions, the both ends of the rotary core are attracted by the fixed core, to substantially double attraction torque to provide large holding power and capacity.

[0013] A third aspect of the present invention makes ends of the rotary core be attracted by the fixed core when the rotary core is rotated to any one of the end positions, arranges the permanent magnet on part of the fixed core within the rotation range of each end of the rotary core, the permanent magnets being oriented so that their magnetic poles may repel each other, and arranges the electromagnetic coil around part of the fixed core out of the part where the permanent magnets are arranged. The third aspect widens the space for arranging the coil.

[0014] A fourth aspect of the present invention makes ends of the rotary core be attracted by the fixed core when the rotary core is rotated to any one of the end positions, arranges the electromagnetic coil around part of the fixed core within the rotation range of each end of the rotary core, and arranges the permanent magnet on part of the fixed core out of the part where the coils are arranged, the permanent magnets being oriented so that their magnetic poles may repel each other. Permanent magnets are usually smaller than electromagnetic

coils, and therefore, the fourth aspect arranges permanent magnets on part of the fixed core outside the rotation range, to enlarge the angle of rotation.

[0015] A fifth aspect of the present invention provides the rotary core with an even number of arms. The arms rotate within the rotation range and are attracted by an even number of faces of the fixed core when the rotary core is rotated to any one of the end positions. The fifth aspect arranges the permanent magnet on part of the fixed core within the rotation range of each arm, the permanent magnets being oriented so that their magnetic poles may repel one another, and arranges the electromagnetic coil around each of the arms. The rotary mechanism of the fifth aspect is appropriate for switchgear of small rotation angle and large torque.

[0016] A sixth aspect of the present invention provides the rotary core with an even number of arms. The arms rotate within the rotation range and have an even number of planes attracted by the fixed core. The sixth aspect arranges the permanent magnet on part of the fixed core within the rotation range of each arm, the permanent magnets being oriented so that their magnetic poles may repel one another, and arranges the electromagnetic coil around part of the fixed core out of the part where the permanent magnets are arranged. The sixth aspect of the present invention widens the space for arranging coils.

[0017] A seventh aspect of the present invention provides the rotary core with an even number of arms. The arms rotate within the rotation range and has an even number of planes attracted by the fixed core. The seventh aspect arranges the electromagnetic coil around part of the fixed core within the rotation range of each arm and arranges the permanent magnet on part of the fixed core out of the part where the coils are arranged, the permanent magnets being oriented so that their magnetic poles may repel one another. Permanent magnets are usually smaller than electromagnetic coils, and therefore, the seventh aspect arranges permanent magnets on part of the fixed core outside the rotation range of each arm, to enlarge an angle of rotation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Figures 1A to 1C are vertical sections showing the operation of a conventional switchgear controlling mechanism;

Fig. 2 is a graph showing the relationship between a stroke and attraction of the conventional switchgear controlling mechanism;

Figs. 3A to 3C are front views showing the structure and opening operation of a rotary mechanism for switchgear according to a first embodiment of the present invention;

Figs. 4A to 4C are front views showing a closing operation of the first embodiment;

Fig. 5 is a graph showing the relationship between attraction torque and rotation angle of the first embodiment with the attraction torque being positive in counterclockwise direction;

Fig. 6 is a sectional view taken along a line VI-VI of Fig. 3A;

Fig. 7 is a view seen in the direction Y2 of Fig. 6, showing a connection between the rotary mechanism of the first embodiment and a movable shaft of a circuit breaker;

Figs. 8A to 8C are front views showing a rotary mechanism for switchgear according to a second embodiment of the present invention;

Figs. 9A to 9C are front views showing a rotary mechanism for switchgear according to a third embodiment of the present invention; and

Figs. 10A to 10C are front views showing a rotary mechanism for switchgear according to a fourth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019] A rotary mechanism for operating switchgear according to the first embodiment of the present invention will be explained with reference to Figs. 3A through 7 in which Figs. 3A to 3C are front views showing the structure of the rotary mechanism and magnetic circuits formed by the rotary mechanism, Fig. 6 is a sectional view taken along the line VI-VI of Fig. 3A, and Fig. 7 is a view seen in the direction Y2 of Fig. 6, showing a connection between the rotary mechanism and a movable shaft of a circuit breaker.

[0020] The structure of the rotary mechanism 10F of the first embodiment will be explained. In Fig. 3A, a fixed core 51 consists of an upper core 51a and a lower core 51b. Two permanent magnets 5 are sandwiched between the upper and lower cores 51a and 51b. The magnetic poles of the magnets 5 are oriented to repel each other. The upper and lower cores 51a and 51b are coupled together with non-magnetic studs 23. The fixed core 51 accommodates a rotary core 52, which is attracted by faces 26a and 26c, or 26b and 26d of the fixed core 51. The rotary core 52 has a shaft 3 supported by a non-magnetic frame 24 fixed to the fixed core 51. An electromagnetic opening coil 4a and an electromagnetic closing coil 4b are fixed to the fixed core 51 and surround the rotary core 52. The rotation of the rotary core 52 is restricted within a predetermined range of angles by the fixed core 51. In Fig. 6, the rotary core 52 and shaft 3 are fixed to each other, and the shaft 3 is rotatably supported with the frame 24 fixed to the fixed core 51. An end of the shaft 3 is fixed to a rotatable disk 25 through which torque generated by the rotary mechanism 10F is transmitted to switchgear.

[0021] In Fig. 7, the disk 25 is connected to a movable shaft 13 of a circuit breaker (not shown) with a pin 14. The shaft 13 is vertically movable within a range shown in Fig. 7. The shaft 13 has a flange 13a, and the rotary

mechanism 10F has a base 15. Between the flange 13a and the base 15, there is a spring 16. The flange 13a compresses the spring 16 at the end of a switchgear opening or disconnecting operation. The shaft 13 is connected to a vacuum valve (not shown) of the breaker. In a closed or connected state, the shaft 13 compresses a wiping spring (not shown) and maintains the closed state.

[0022] The operation of the rotary mechanism 10F will be explained. In Fig. 3A, the rotary core 52 is attracted by the fixed core 51 at one end of the rotation range to establish a switchgear closed/connected state. In this state, the rotary mechanism 10F forms two magnetic circuits depicted with dashed lines. Namely, the left and right permanent magnets 5 produce flows of magnetic flux that pass through the upper core 51a, merges with each other in the rotary core 52, again separate from each other in the lower core 51b, and reach the respective magnets 5, to form the two magnetic circuits. The faces 26a and 26c of the fixed core 51 attract each end of the rotary core 52 to produce clockwise torque, which drives the shaft 3 to compress the wiping spring.

[0023] In Fig. 3B, an opening /disconnecting operation is started by exciting the coil 4a to cancel the magnetic flux of the magnets 5. Namely, the rotary core 52 surrounded with the coil 4a passes magnetic flux that cancels the magnetic flux of the magnets 5, thereby weakening torque acting on the rotary core 52. When the torque is weakened below the resilience of the wiping spring, the rotary core 52 starts to rotate counterclockwise to start the opening operation.

[0024] During the rotation of the rotary core 52, a gap between each end of the rotary core 52 and the fixed core 51 widens to weaken attraction acting on the rotary core 52. However, the rotary core 52 and disk 25 have the moment of inertia to continuously rotate the rotary core 52 against friction up to the other end of the rotation range (flywheel effect).

[0025] In Fig. 3C, the opening operation is just before completion. Due to the rotation, the rotary core 52 reversely passes the magnetic flux generated by the magnets 5. At this time, the direction of themagnetic flux generatedby the coil 4a is unchanged in the rotary core 52. Consequently, the dashed-line magnetic flux and solid-line magnetic flux of Fig. 3C enhance each other to increase counterclockwise torque at the end of the rotation range of the rotary core 52. Further, the rotational energy of the rotary core 52 is added to the counterclockwise torque, to compress the spring 16 through the shaft 3 and disk 25 and complete the opening operation.

[0026] Under this state, counterclockwise torque generated by the magnets 5 is designed to exceed torque caused by the resilience of the spring 16. As a result, attraction by the magnets 5 alone holds the rotary core 52 at the faces 26b and 26d of the fixed core 51, to maintain the open state even after the coil 4a is de-energized.

[0027] The first embodiment is achievable by tentatively dividing the fixed core 51 into four sections at the four faces 26a to 26d and by arranging one magnet 5 between the faces 26b and 26c within the rotation range of one end of the rotary core 52 and the other magnet 5 between the faces 26d and 26awithin the rotation range of the other end of the rotary core 52.

[0028] A closing/connecting operation of the rotary mechanism 10F will be explained. The coil 4b is excited oppositely to the opening operation, to achieve the closing operation that is opposite to the opening operation. In Fig. 4A, the rotary core 52 is attracted to one end of the rotation range like Fig. 3C, to establish a switchgear open or disconnected state. At this time, the magnets 5 form magnetic circuits depicted with dashed lines. Namely, flows of magnetic flux generated by the magnets 5 pass through the upper core 51a, merge with each other in the rotary core 52, again separate from each other in the lower core 51b, and return to the respective magnets 5, thereby forming the two magnetic circuits. As a result, the faces 26b and 26d of the fixed core 51 attract the ends of the rotary core 52, to produce counterclockwise torque, which compresses the spring 16 through the shaft 3.

[0029] In Fig. 4B, the closing operation is started by exciting the coil 4b in a direction to cancel the magnetic flux generated by the magnets 5. Namely, the rotary core 52 surrounded with the coil 4b passes magnetic flux that cancels the magnetic flux of the magnets 5, thereby weakening torque acting on the rotary core 52. When the torque is weakened below the resilience of the spring 16, the rotary core 52 starts to rotate clockwise to start the closing operation.

[0030] During the rotation of the rotary core 52, inertial movement/angular momentum relating to moment of inertia mentioned above overcomes friction, to continuously rotate the rotary core 52 up to the other end of the rotation range.

[0031] In Fig. 4C, the closing operation is just before completion. Due to the rotation, the rotary core 52 reversely passes the magnetic flux generated by the magnets 5. At this time, the direction of magnetic flux generated by the coil 4b is unchanged in the rotary core 52. Consequently, the dashed-line magnetic flux and solid-line magnetic flux of Fig. 4C enhance each other to steeply increase clockwise torque at the end of the rotation range. Further, the rotation energy of the rotary core 52 is added to the clockwise torque, to compress the wiping spring through the shaft 3 and disk 25 and complete the closing operation. This state of Fig. 4C is identical to that of Fig. 3A in which the magnetic circuits formed by the magnets 5 maintain the closed state even after the coil 4b is de-energized.

[0032] Effect of the first embodiment will be explained. Figure 5 is a graph showing the relationship between attraction torque and rotation angle of the rotary core 52 during opening/closing operations with counterclockwise torque being positive. A dashed line represents torque generated by the magnets 5 alone, and solid lines represent total attraction torque for an opening op-

eration (C-F) and a closing operation (G-H). Dot-and-dash lines represent the resilience of the springs with signs thereof being inverted. A point A is a closed state in which torque for attracting the rotary core 52 is greater than the resilience B of the wiping spring. During the opening operation, the excitation of the coil 4a decreases the attraction torque on the rotary core 52 to C lower than the resilience of the wiping spring, to rotate the rotary core 52 in the opening direction. Around an intermediate position N, attraction on the rotary core 52 is small, however, the moment of inertia mentioned above helps continuous rotation of the rotary core 52 up to the opening end. At the opening end, attraction torque F stronger than the resilience D of the spring 16 attracts the rotary core 52, to complete the opening operation. During the open state with no current, the attraction torque E of the magnets 5 exceeds the resilience D of the spring 16, to maintain the open state even after the coil 4a is de-energized. The closing operation proceeds in an opposite manner.

[0033] In this way, at one end of the rotation range corresponding to the connected/closed state of Fig. 3A, the magnets 5 form magnetic circuits that produce clockwise torque to maintain the closed state by the magnets 5 alone. At the other end of the rotation range corresponding to the disconnected/open state of Fig. 4A, the magnets 5 form magnetic circuits that produce counterclockwise torque to maintain the open state by the magnets 5 alone. The rotary mechanism 10F of the first embodiment thus provides a bistable state. At each of the open and closed positions, the rotary core 52 is attracted by two faces of the fixed core 51 that are substantially point-symmetric. Namely, the rotary core 52 is attracted by a couple of torque generated by opposing forces. In other words, the rotary core 52 receives attraction torque that is substantially double the conventional one.

[0034] At the start of the opening operation, the coil 4a or 4b generates magnetic flux that weakens attraction by the magnets 5. As a result, the rotary core 52 is put in amagnetically unstable state. At the end of the opening operation, the magnetic flux generated by the coil 4a or 4b works to enhance the attraction of the magnets 5. In this way, the coil 4a provides an attraction switching function for the magnets 5. If there are only the magnets 5, they establish a magnetically bistable state.

[0035] At the end of the opening operation, attraction acting on the rotary core 52 steeply increases to compress the spring 16. This simple structure of the rotary mechanism 10F with the attraction switching function and the moment of inertia of the rotary shaft 52 and disk 25 is capable of driving the rotary core 52 even for a long stroke. At the end of the opening operation, the spring 16 is deformed to store resilient energy for driving the next closing operation. The spring 16 also relaxes shocks by the impacts of the rotary core 52 on the fixed core 51. The resilient energy stored in the spring 16 for the next closing operation helps reduce an excitation current to be applied to the coil 4a or 4b. The shock absorbing effect of the spring 16 avoids damage on the fixed core 51 and rotary core 52, to improve the reliability of the rotary mechanism 10F.

[0036] The first embodiment forms all magnetic paths on a rotation plane, to make the rotary mechanism 10F thin. The fixed core 51 or the rotary core 52 may be made of silicon steel plates 17 (Fig. 6) laminated along a rotation axis, to reduce eddy currents and realize high-speed response.

[0037] The disk 25 fixed to the shaft 3 may optionally be designed to provide required moment of inertia. Namely, the rotary core 52 may first be designed to form optimum magnetic paths, and then, the disk 25 may be designed to compensate a shortage in the moment of inertia that is necessary for overcoming friction on the rotary core 52. This ensures the rotary operating mechanism 10F achieving a required long stroke for switchgear opening and closing operations. The shape of the disk 25 is not limited to a circle. It may have an optional shape if it is rotatable and provides required moment of inertia.

[0038] The first embodiment arranges the coils 4a and 4b on the fixed core 51 to surround the rotary core 52. If the rotating speed of the rotary core 52 is slow, the coils 4a and 4b may be fixed to the rotary core 52 so that the coils may rotate together with the rotary core. If the rotary core 52 produces sufficient moment of inertia, the disk 25 may be a simple lever.

[0039] Figures 8A to 8C show a rotary mechanism for switchgear according to the second embodiment of the present invention. This and other embodiments that follow are based on the first embodiment, and therefore, the following explanation will mainly be made for the characteristic operations and effects of magnetic circuits formed with fixed cores, rotary cores, permanent magnets, and electromagnetic coils of the embodiments.

[0040] In Fig. 8A, the rotary mechanism 10G of the second embodiment has a fixed core 61 that sandwiches two permanent magnets 5, which are oriented so that their magnetic poles may repel each other. The fixed core 61 accommodates a rotary core 62 alternatively attracted by faces 26a and 26c, or faces 26b and 26d of the fixed core 61. Upper and lower parts of the fixed core 61 have electromagnetic coils 4, respectively.

[0041] The operation of the rotary mechanism 10G will be explained. In Fig. 8A, the rotary mechanism 10G is in a closed or connected state. In this state, the rotary mechanism 10G forms magnetic circuits depicted with dashed lines. Namely, flows of magnetic flux generated by the left and right magnets 5 pass through the rotary core 62 and return to the respective magnets 5. As a result, the faces 26a and 26c attract the rotary core 62 clockwise and compress a wiping spring (not shown) through a shaft 3.

[0042] In Fig. 8B, a switchgear opening or disconnect-

ing operation starts. The coils 4 are excited to generate magnetic fluxes in the fixed core 61 directing at positive horizontal direction X+ so as to cancel the magnetic flux generated by the magnets 5 and weaken the attraction of the faces 26a and 26c acting on the rotary core 62. When the attraction is weakened below the resilience of the wiping spring, the rotary core 62 starts to rotate counterclockwise to start the opening operation. During the rotation, attraction on the rotary core 62 decreases. However, inertial movement of the rotary core 62 and a disk 25 overcomes friction, to continuously rotate the rotary core 62 up to the other end of a rotation range of the rotary core 62.

[0043] In Fig. 8C, the opening operation is just before completion. Due to the rotation, the rotary core 62 reversely passes the magnetic flux generated by the magnets 5. At this time, the direction of the magnetic flux generated by the coils 4 is unchanged in the rotary core 62. Consequently, the dashed-line magnetic flux and solid-line magnetic flux of Fig. 8C enhance each other to increase counterclockwise torque at the end of the rotation range of the rotary core 62. Further, the rotation energy of the rotary core 62 and disk 25 is joined to the counterclockwise torque, to compress a spring arranged outside the rotary mechanism 10G and complete the opening operation. In this state, counterclockwise torque generated by the magnets 5 alone is designed to exceed torque caused by the resilience of the spring. As a result, the attraction of the magnets 5 alone holds the rotary core 62 at the faces 26b and 26d of the fixed core 61, to maintain the open state even after the coils 4 are de-energized. A closing or connecting operation is opposite to the opening operation and is executed by reversely exciting the coils 4.

[0044] The second embodiment is achievable by tentatively dividing the fixed core 61 into four sections at the four attraction faces 26a to 26d, by arranging one magnet 5 between the faces 26b and 26c within the rotation range of one end of the rotary core 62 and the other magnet 5 between the faces 26d and 26a within the rotation range of the other end of the rotary core 62, and by arranging one coil 4 between the faces 26a and 26b out of the part where the magnets 5 are arranged and the other coil 4 between the faces 26c and 26d out of the part where the magnets 5 are arranged.

[0045] The effect of the second embodiment will be explained. The second embodiment is based on the first embodiment and is formed by arranging the two coils 4 around the fixed core 61. The structure of the second embodiment is simple to provide two attraction faces for each magnetic circuit and realize the attraction switching function and a long stroke, like the first embodiment. Compared with the first embodiment, the second embodiment widens the space for arranging coils.

[0046] The second embodiment may have opening and closing coils separately. These coils are used for opening and closing operations, respectively. This arrangement is capable of easily carrying out an opening operation just after closure (a so-called C-O operation), and therefore, is applicable to high-speed-response switchgear. Due to the simple structure, the rotary mechanism of the second embodiment is inexpensive and reliable.

[0047] Figures 9A to 9C show a rotary mechanism for switchgear according to the third embodiment of the present invention. The third embodiment is basically achievable by replacing the coils 4 and magnets 5 of the second embodiment with each other. The structure of the rotary mechanism 10H of the third embodiment will be explained. In Fig. 9A, the rotary mechanism 10H has a fixed core 71. Two permanent magnets 5 are arranged in upper and lower parts of the fixed core 71, respectively, and are oriented so that their magnetic poles repel each other. The fixed core 71 accommodates a rotary core 72 to be attracted alternatively by upper and lower faces 26a and 26c, or faces 26b and 26d of the fixed core 71. Electromagnetic coils 4 are arranged around left and right parts of the fixed core 71, respectively, to generate magnetic flux in the fixed core 71 in vertical directions Z+ and Z-.

[0048] The operation of the rotary mechanism 10H will be explained. In Fig. 9A, the rotary mechanism 10H forms magnetic circuits depicted with dashed lines. Namely, the upper and lower magnets 5 generate flows of magnetic flux, which pass through the rotary core 72 and return to the respective magnets 5. As a result, the faces 26a and 26c of the fixed core 71 attract the rotary core 72 clockwise to compress awiping spring (not shown) through a shaft 3.

[0049] In Fig. 9B, an opening or disconnecting operation is started. The left and right coils 4 are excited to generate magnetic flux directing at negative vertical direction Z- so as to cancel the magnetic flux generated by the magnets 5 and weaken the attraction of the faces 26a and 26c acting on the rotary core 72. When the attraction is weakened below counterclockwise torque produced by the resilience of the wiping spring, the rotary core 72 starts to leave the faces 26a and 26c androtate counterclockwise, thereby starting the opening operation. During the rotation, attraction acting on the rotary core 72 decreases. However, an inertial movement of the rotary core 72 and a disk 25 overcomes friction to continuously rotate the rotary core 72 up to the other end of a rotation range of the rotary core 72.

[0050] In Fig. 9C, the opening operation is just before completion. Due to the rotation, the rotary core 72 reversely passes the magnetic flux generated by the coils 4. At this time, the direction of the magnetic flux generated by the magnets 5 is unchanged in the rotary core 72. Consequently, the dashed-line magnetic flux and solid-line magnetic flux of Fig. 9C enhance each other, to increase counterclockwise torque at the end of the rotation of the rotary core 72. Further, the rotation energy of the rotary core 72 is joined to the counterclockwise torque, to compress a spring arranged outside the rotary mechanism 10H and complete the opening operation.

[0051] Under this state, counterclockwise torque generated by the magnets 5 alone is designed to surpass the resilience of the spring. As a result, attraction by the magnets 5 alone holds the rotary core 72 at the faces 26b and 26d of the fixed core 71, to maintain the open state even after the coils 4 are de-energized. A closing or connecting operation is opposite to the opening operation and is executed by reversely exciting the coils 4.

[0052] The third embodiment is achievable by tentatively dividing the fixed core 71 into four sections at the four attraction faces 26a to 26d, by arranging one coil 4 between the faces 26b and 26c within the rotation range of one end of the rotary core 72 and the other coil 4 between the faces 26d and 26a within the rotation range of the other end of the rotary core 72, and by arranging one magnet 5 between the faces 26a and 26b out of the part where the coils 4 are arranged and the other magnet 5 between the faces 26c and 26d out of the part where the coils 4 are arranged.

[0053] The effect of the third embodiment will be explained. The third embodiment is based on the second embodiment and is formed by replacing the coils 4 and magnets 5 of the second embodiment with each other. The structure of the third embodiment is simple to provide two attraction faces for each of the open and closed states and realize a magnetically bistable state, the attraction switching function, and a long stroke, like the second embodiment. The third embodiment is specifically effective when a large rotation angle is required. When the rotation range of the rotary core 72 is increased, the distance between the faces 26a and 26b and the distance between the faces 26c and 26d outside the rotation range of the rotary core 72 are shortened, and therefore, it is hardly possible to arrange the coil 4 in such a short distance. In this case, the thickness of the magnet 5 is usually in the range of 10 to 20 mm, and therefore, the third embodiment arranges the magnet 5 in each area outside the rotation range of the rotary core 72, and the coils 4 in the rotary range. As a result, the rotary mechanism 10H of the third embodiment allows a large rotation angle.

[0054] Figures 10A to 10C show a rotary mechanism for switchgear according to the fourth embodiment of the present invention. The fourth embodiment is based on the first embodiment and increases the number of magnetic poles of the first embodiment. The structure of the rotary mechanism 10I of the fourth embodiment will be explained. In Fig. 10A, the rotary mechanism 10I has a rotary core 82 having four arms. The rotary core 82 is arranged at the center of a fixed core 81 of ring shape. The fixed core 81 has four protrusions 81a and eight attraction faces 26a to 26h to attract the rotary core 82 at each end of a rotation range of the rotary core 82. If the fixed core 81 is tentatively divided at the faces 26a to 26h into eight sections, the sections 26a-26b, 26c-26d, 26e-26f, and 26g-26h correspond each to the rotation range of each arm of the rotary core 82. Permanent magnets 5 are arranged in these sections, respectively, and are oriented so that their magnetic poles repel each other. The arms of the rotary core 82 are alternately provided with an electromagnetic opening coil 4a and an electromagnetic closing coil 4b to generate radial magnetic flux.

[0055] The operation of the rotary mechanism 10I will be explained. In Fig. 10A, the rotary mechanism 10I is in a closed state. The magnets 5 on the fixed core 81 are oriented so that their magnetic poles repel each other. Consequently, magnetic flux generated by one magnet 5 does not pass through the other magnets 5. Instead, magnetic flux from each magnet 5 emanates from one pole thereof, passes through corresponding arms of the rotary core 82, and returns to the other pole of the magnet 5 in question. As a result, the four magnets 5 form four magnetic circuits, and the rotary core 82 is attracted clockwise by the four faces 26b, 26d, 26f, and 26h of the fixed core 81.

[0056] In Fig. 10B, a pair of the coils 4a are excited to generate magnetic flux oriented toward a rotation axis, to form magnetic circuits depicted with solid lines, which weaken the magnetic flux generated by the magnets 5. This weakens attraction torque working on the rotary core 82. When the attraction torque is weakened below the resilience of a wiping spring, the rotary core 82 starts to rotate counterclockwise, thereby starting the opening operation. During the rotation, attraction acting on the rotary core 82 decreases. However, the inertial movement of the rotary core 82, etc., overcomes friction, to continuously rotate the rotary core 82 up to the other end of the rotation range of the rotary core 82.

[0057] In Fig. 10C, the opening operation is just before completion. Due to the rotation, the arms of the rotary core 82 reversely pass the magnetic flux generated by the magnets 5. At this time, the direction of the magnetic circuits generated by the coils 4a is unchanged in the arms of the rotary core 82. Consequently, the dashed-line magnetic flux and solid-line magnetic flux of Fig. 10C enhance each other, to increase counterclockwise torque at the end of the rotation range of the rotary core 82. Further, the rotation energy of the rotary core 82 is added to the counterclockwise torque, to compress a spring arranged outside the rotary mechanism 10I and complete the opening operation.

[0058] Under this state, counterclockwise torque generated by the magnets 5 alone is designed to surpass the resilience of the spring. As a result, attraction by the magnets 5 alone holds the rotary core 82 at the faces 26a, 26c, 26e, and 26g of the fixed core 81, to maintain the open state even after the coils 4a are de-energized. A closing or connecting operation is opposite to the opening operation and is executed by exciting the coils 4b.

[0059] The effect of the fourth embodiment will be explained. The fourth embodiment is achievable by increasing the number of magnetic poles of the first embodiment to four. More generally, the fourth embodiment is achievable with an even number of magnetic poles.

The fourth embodiment provides two attraction faces for each magnetic circuit and realizes a magnetically bistable state, the attraction switching function, and a long stroke. The fourth embodiment may have four or more magnetic poles, and in this case, may be applicable to switchgear that needs a small rotation angle and large torque. The rotary mechanism of the fourth embodiment is manufacturable by employing many inexpensive permanent magnets of small magnetic moment, to reduce the total cost of the rotary mechanism. The fourth embodiment is also achievable with a fixed inner core and a rotatable outer core.

[0060] The fourth embodiment employs an even number of magnetic poles, arranges the magnet 5 on part of the fixed core 81 within the rotation range of each arm of the rotary core 82, and arranges the coil 4 around each arm of the rotary core 82. With an even number of magnetic poles, the magnets and coils of the fourth embodiment may be arranged like the second and third embodiments. Namely, each magnet may be arranged on part of the fixed core within the rotation range of each rotary core arm, and the coils may be arranged around part of the fixed core out of the part where the magnets are arranged, like the second embodiment.

[0061] Alternatively, each coil may be arranged around part of the fixed core within the rotation range of each rotary core arm, and the magnets may be arranged on part of the fixed core out of the part where the coils are arranged, like the third embodiment. These arrangements realize the effects and operations of the second and third embodiments in addition to the effect and operation of the fourth embodiment.

Claims

1. A rotary mechanism for switchgear, comprising:

    a fixed core;
    a rotary core rotatable with respect to the fixed core within a rotation range limited by end positions corresponding to switchgear open and closed positions;
    spring means for accumulating resilience when the rotary core is rotated to any one of the end positions;
    a permanent magnet device, the permanent magnet device being consist of at least two permanent magnets, each of the permanent magnet forming a closed magnetic path passing through the fixed core and rotary core, the magnetic path generating attraction greater than the resilience of the spring means to hold the rotary core at the end position when the rotary core is rotated to any one of the end positions; and
    an electromagnetic device, the electromagnetic device being consist of at least one electromagnetic coil, the electromagnetic coil being excited to generate magnetic flux, wherein
    when the rotary core being at one of the end positions, the magnetic flux in the rotary core generated by each electromagnetic coil of the electromagnetic device forms a magnetic path oriented opposite to the magnetic path formed by the permanent magnet device, the magnetic path formed by the electromagnetic coil weakening the attraction by the permanent magnet device lower than the resilience of the spring means; and
    when the rotary core has been rotated to the other end position, the permanent magnet device and the electromagnetic device form magnetic paths being oriented in the same direction in the rotary core.

2. The rotary mechanism for switchgear of claim 1, wherein:

    ends of the rotary core are attracted by predetermined parts of the fixed core, respectively, when the rotary core is rotated to any one of the end positions;
    each of the permanent magnets is arranged on part of the fixed core within the rotation range of each end of the rotary core, the permanent magnets being oriented so that their magnetic poles may repel each other; and
    the electromagnetic device is arranged to surround the rotary core.

3. The rotary mechanism for switchgear of claim 1, wherein:

    ends of the rotary core are attracted by the fixed core when the rotary core is rotated to any one of the end positions;
    each of the permanent magnets is arranged on part of the fixed core within the rotation range of each end of the rotary core, the permanent magnets being oriented so that their magnetic poles may repel each other; and
    the electromagnetic coil is arranged around part of the fixed core out of the part where the permanent magnets are arranged.

4. The rotary mechanism for switchgear of claim 1, wherein:

    ends of the rotary core are attracted by the fixed core when the rotary core is rotated to any one of the end positions;
    the electromagnetic coil is arranged around part of the fixed core within the rotation range of each end of the rotary core; and
    each of the permanent magnets is arranged on

part of the fixed core out of the part where the electromagnetic coils are arranged, the permanent magnets being oriented so that their magnetic poles may repel each other.

5. The rotary mechanism for switchgear of claim 1, wherein:

the rotary core has an even number of arms radially extending from a rotation center, the arms being rotatable within the rotation range and being attracted by an even number of faces of the fixed core when the rotary core is rotated to any one of the end positions;
each of the permanent magnets is arranged on part of the fixed core within the rotation range of each of the arms, the permanent magnets being oriented so that their magnetic poles may repel one another; and
each of the electromagnetic coils is arranged around each of the arms.

6. The rotary mechanism for switchgear of claim 1, wherein:

the rotary core has an even number of arms radially extending from a rotation center, the arms being rotatable within the rotation range and being attracted by an even number of faces of the fixed core when the rotary core is rotated to any one of the end positions;
each of the permanent magnet is arranged on part of the fixed core within the rotation range of each of the arms, the permanent magnets being oriented so that their magnetic poles may repel one another; and
each of the electromagnetic coils is arranged around part of the fixed core out of the part where the permanent magnets are arranged.

7. The rotary mechanism for switchgear of claim 1, wherein:

the rotary core has an even number of arms radially extending from a rotation center, the arms being rotatable within the rotation range and being attracted by an even number of faces of the fixed core when the rotary core is rotated to any one of the end positions;
each of the electromagnetic coils is arranged around part of the fixed core within the rotation range of each of the arms; and
each of the permanent magnets is arranged on part of the fixed core out of the part where the electromagnetic coils are arranged, the permanent magnets being oriented so that their magnetic poles may repel one another

8. The rotary mechanism for switchgear of any one of claims 1 to 7, wherein:
the permanent magnets and electromagnetic coils form magnetic paths on a rotation plane of the rotary core.

9. The rotary mechanism for switchgear of any one of claims 1 to 7, wherein:
the rotary core is provided with movable means that is rotatable with the rotary core.

10. The rotary mechanism for switchgear of any one of claims 1 to 7, wherein:
at least one of the fixed core and rotary core is made of silicon steel plates laminated along a rotation axis of the rotary core.

FIG.1A

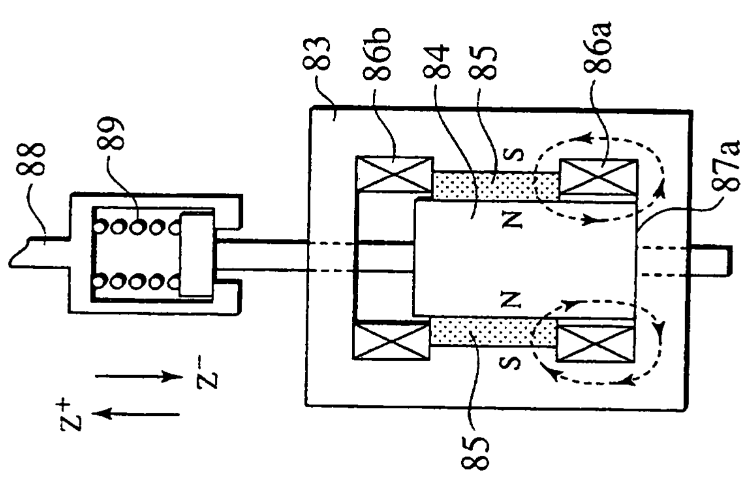

FIG.1B

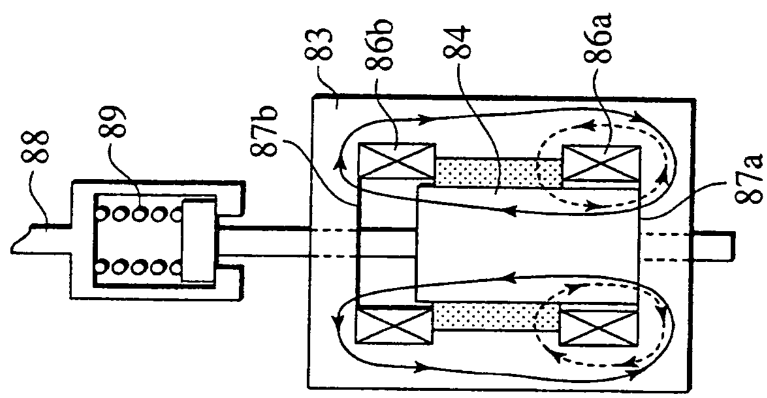

FIG.1C

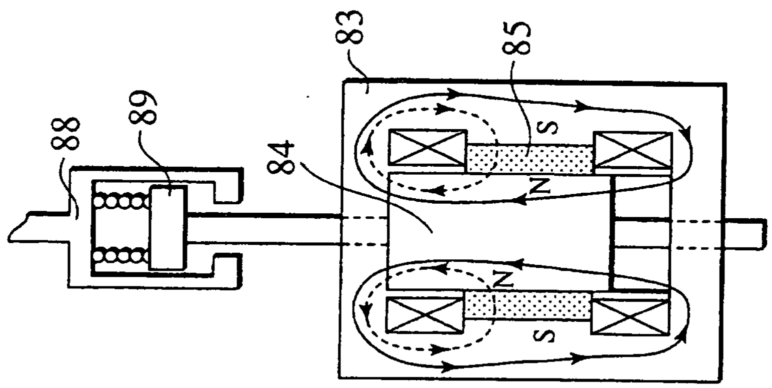

FIG.2

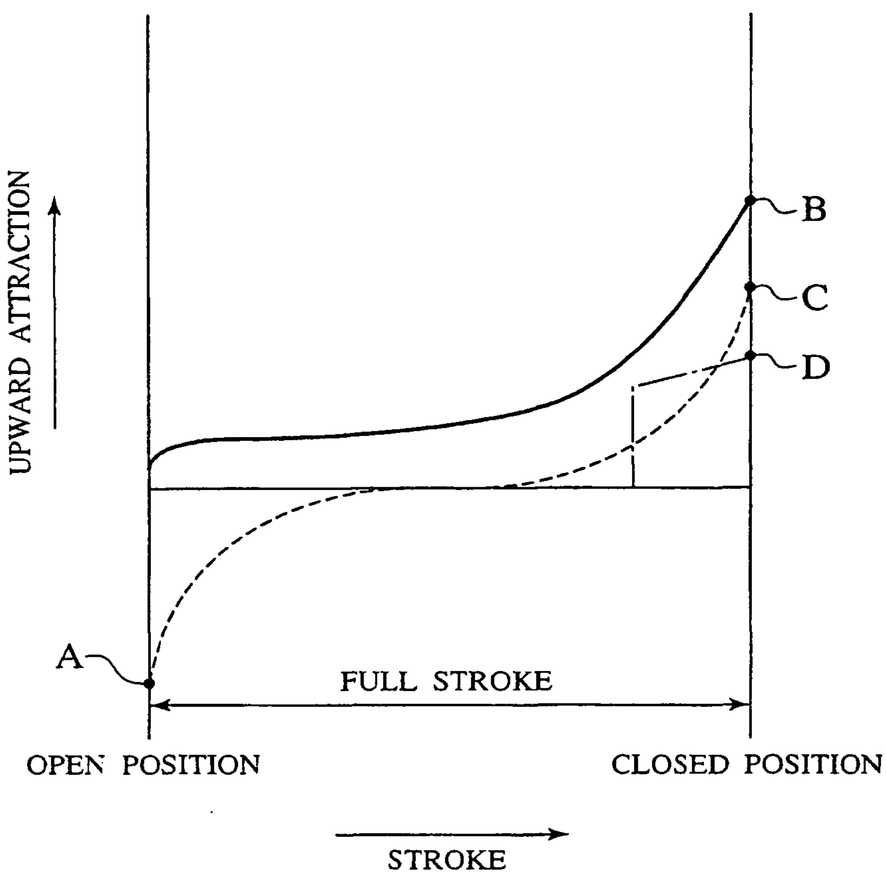
UPWARD ATTRACTION
B
C
D
A
FULL STROKE
OPEN POSITION
CLOSED POSITION
STROKE

FIG.3A

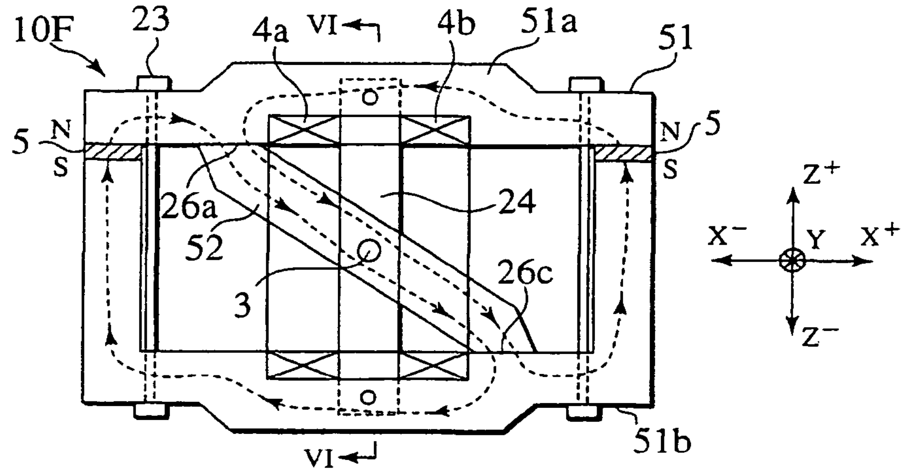

FIG.3B

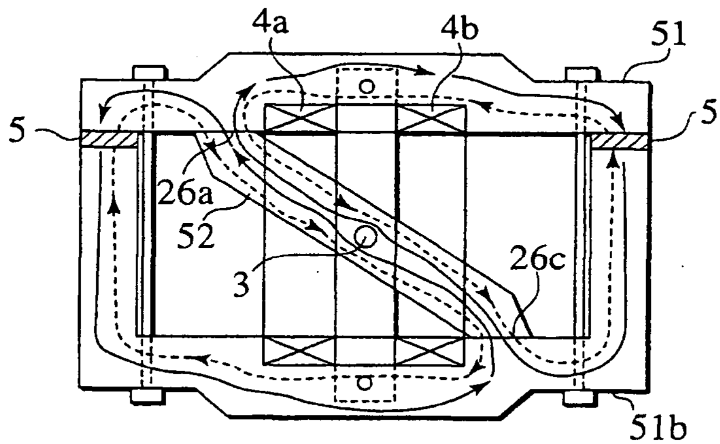

FIG.3C

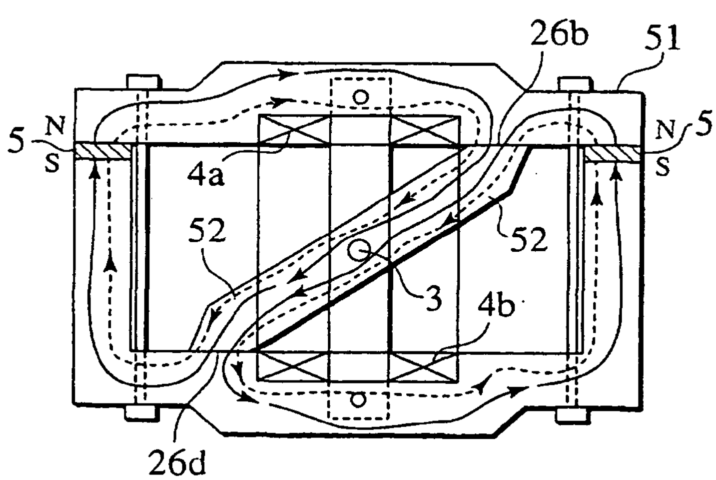

FIG.4A

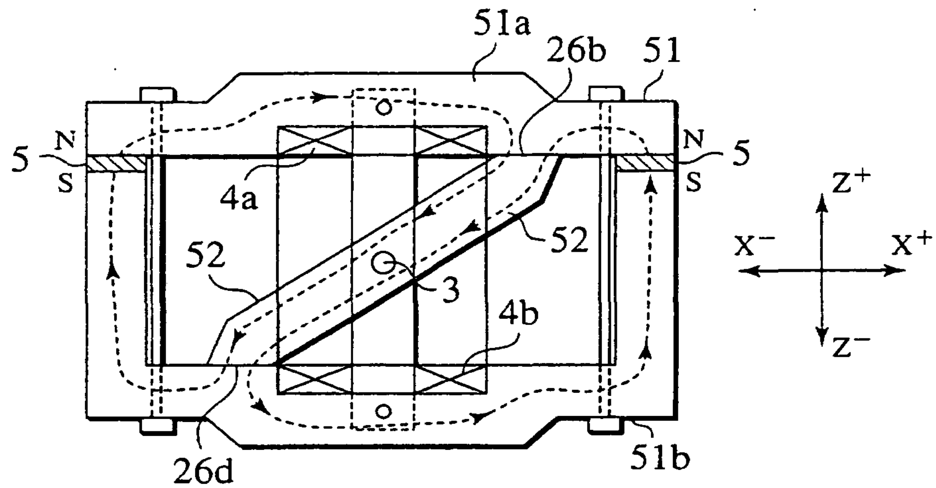

FIG.4B

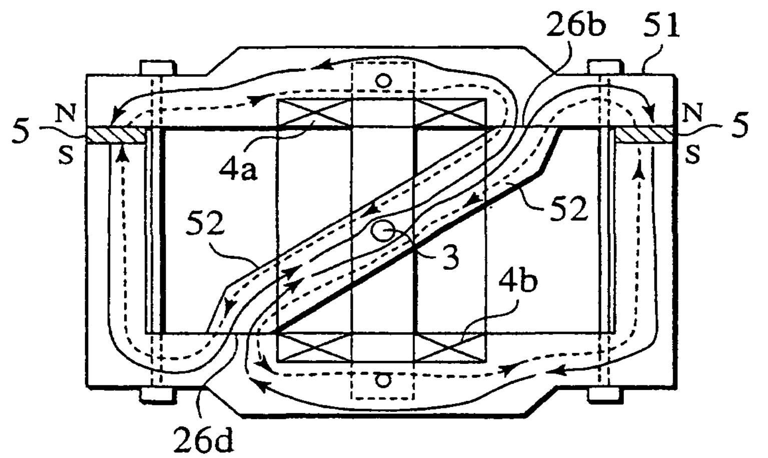

FIG.4C

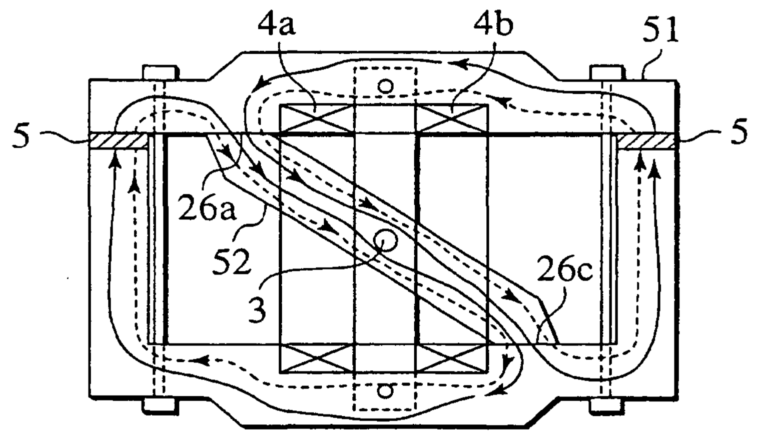

FIG.5

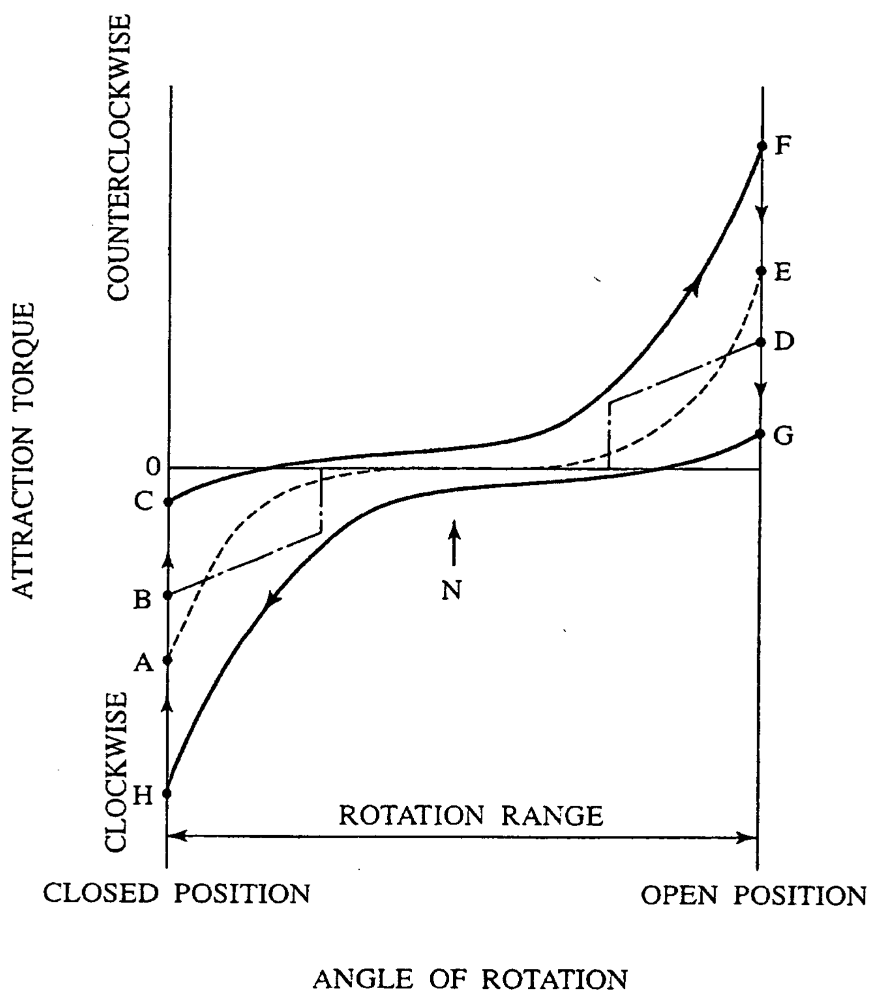
COUNTERCLOCKWISE
ATTRACTION TORQUE
CLOCKWISE
0
C
B
A
H
F
E
D
G
N
ROTATION RANGE
CLOSED POSITION
OPEN POSITION
ANGLE OF ROTATION

FIG.6

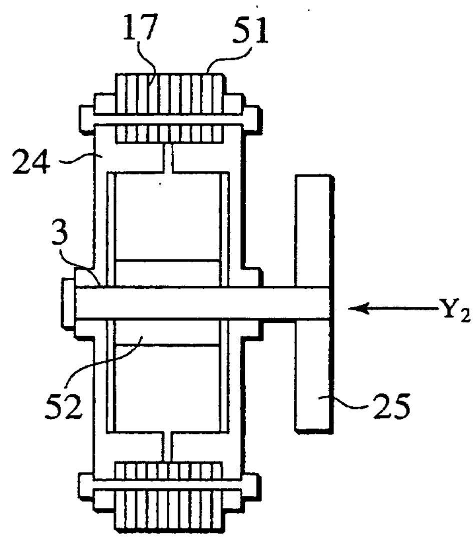

FIG.7

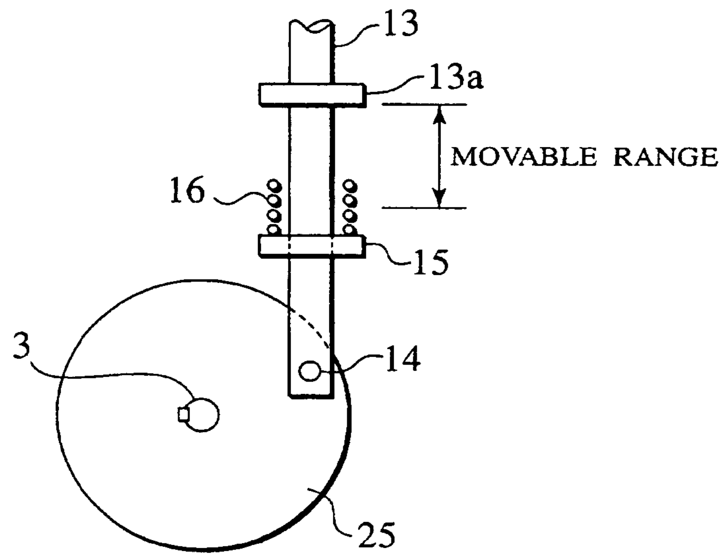

FIG.8A

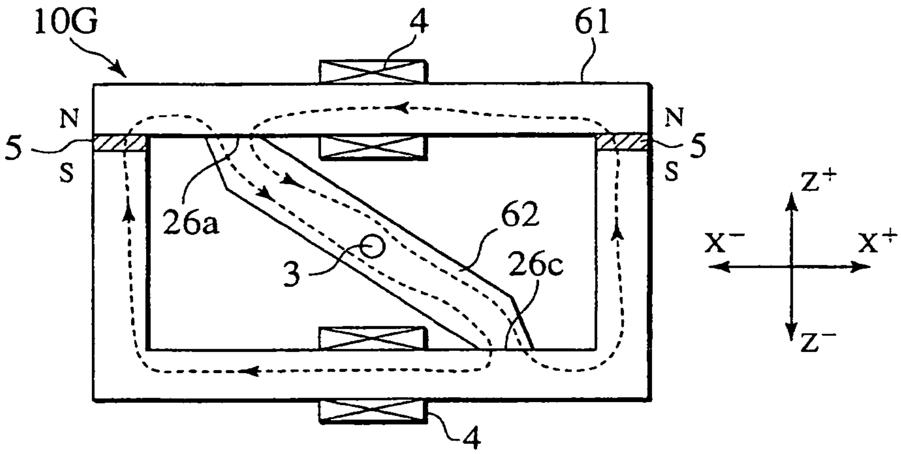

FIG.8B

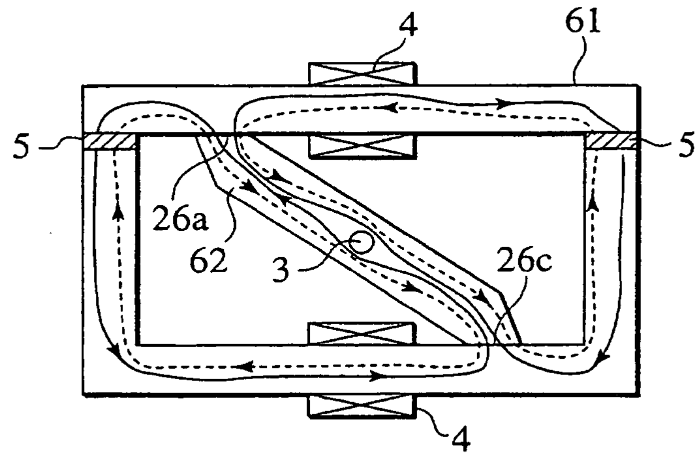

FIG.8C

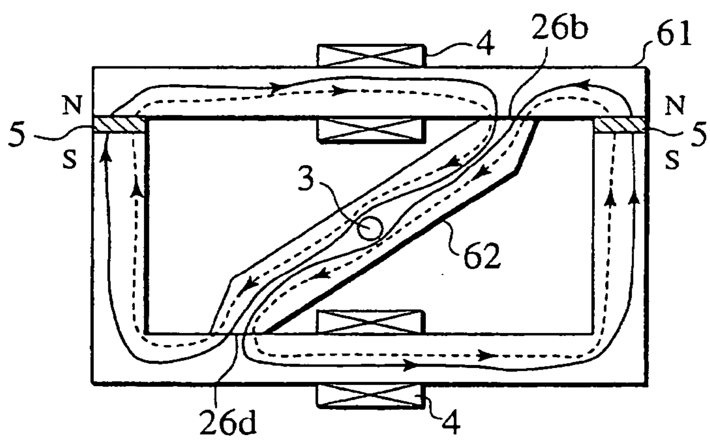

FIG.9A

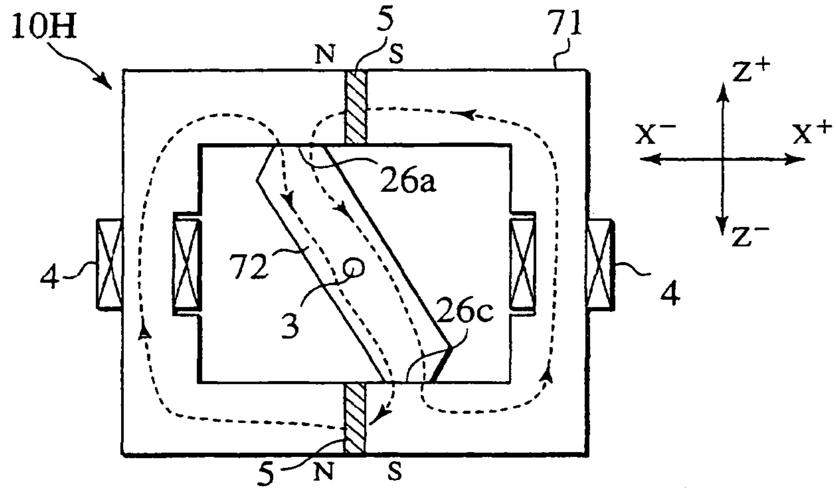

FIG.9B

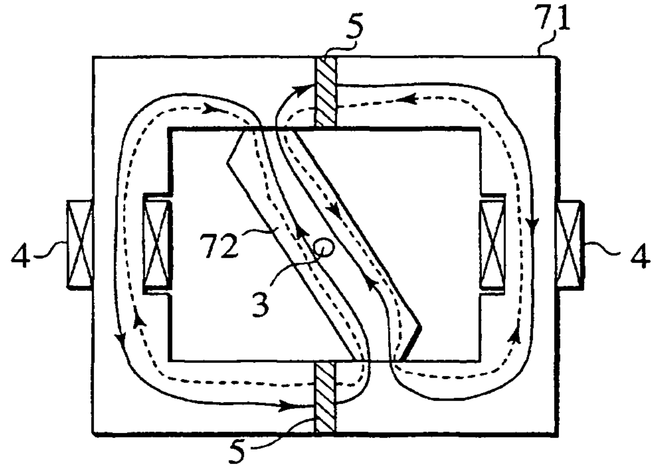

FIG.9C

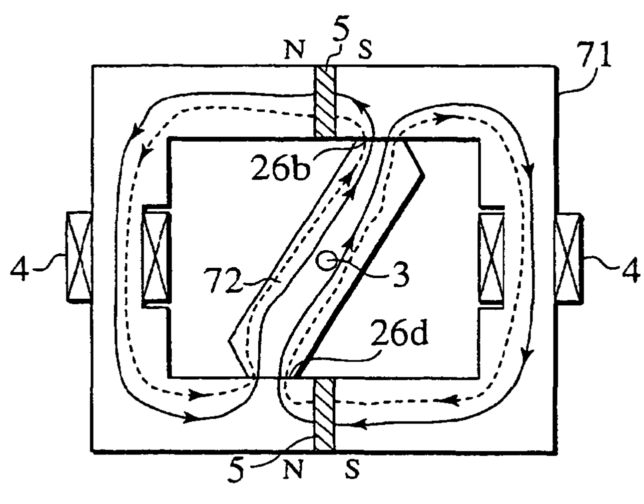

FIG.10A

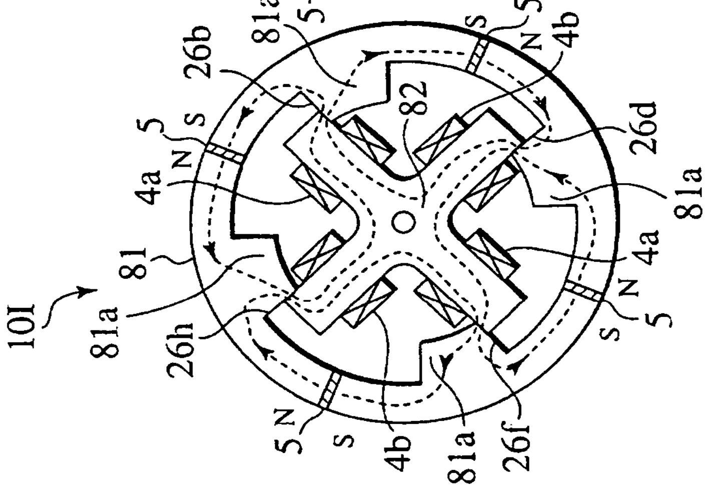

FIG.10B

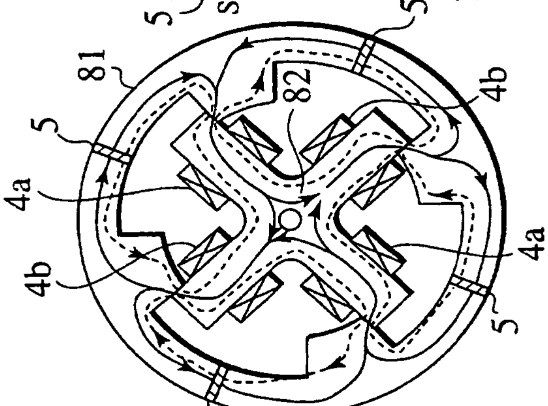

FIG.10C